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(71) Applicant: AIRNET COMMUNICATION CORPORATION [US/US]; Suite 300, 100 Rialto Place, Melbourne, FL 32901 (US).

(72) Inventor: POOR, Victor, D.; 1208 E. River Drive #302, Melbourne, FL 32901 (US).

(74) Agent: THIBODEAU, David, J., Jr.; AirNet Communication Corporation, Suite 300, 100 Rialto Place, Melbourne, FL 32901 (US).

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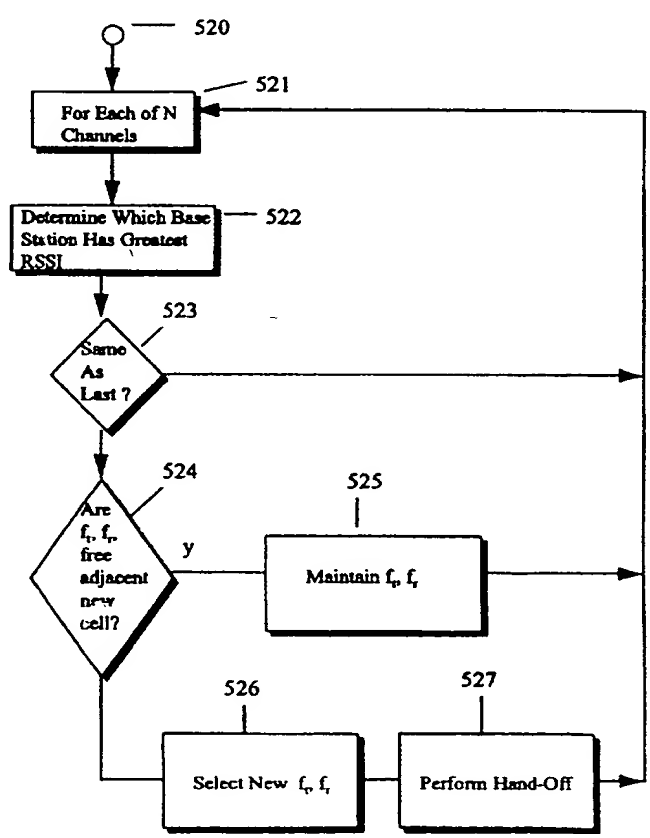
(57) Abstract

A cellular communications system making use of wideband digital transceivers and fixed-to-mobile frequency assignments to provide to determine an optimum active base station within a group of base stations. Each base station transceiver can receive and transmit on each one of the N channel frequencies assigned to the service provider. As a result, the system can allow the mobile units to maintain the same frequency from cell to cell whenever possible. To perform diversity combining, each base station uses a single receive antenna to provide a receive signal strength indication, or RSSI, for each of the channel frequencies available to the service provider, and then reports the list of RSSIs for each channel to a central base station controller. The base station controller can then determine which base station is receiving the signal from a remote mobile unit with the greatest received signal power by simply comparing the relative magnitudes of the RSSIs. The central controller than assigns the base station having the strongest received signal strength to service the mobile unit. The invention not only minimizes the required amount of hand-off processing but also reduces the number of antennas needed to provide diversity reception to one per cell.



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CELLULAR TELEPHONE SYSTEM MAINTAINING CHANNEL FREQUENCY AT HAND-OFF

FIELD OF THE INVENTION

This invention relates generally to cellular communication systems, and in particular to a system which uses a wideband base station transceiver at each base station site, to determine an optimum transmitting base station while minimizing the need to perform call hand-off.

BACKGROUND OF THE INVENTION

The ever-increasing demand for wireless communication services, such as cellular mobile telephone (CMT), digital cellular network (DCN), and personal communication services (PCS) requires the operators of such systems to make maximum effective use of the available radio frequency bandwidth. Consider, for example, that most system operators are only allocated a fixed number of channel frequencies to service a given geographic territory. In an effort to make the best use of the allocated frequency space, the geographic territory is divided into a number of portions, called cells. A like number of radio base stations are then deployed to service mobile radio traffic in the cell, with there typically being one base station located in each cell.

The system operator must also determine how to best split up the allocated frequency channels among the cells. Indeed, an extensive study is often necessary to determine how to minimize interference between adjacent base stations as well as how to best reuse the channels, that is, how to allocate each channel to more than one cell in the territory.

In such a scenario, only a fixed, particular set of transmit and receive operating frequencies are thus made available to service the mobile units operating in a particular cell. As a result, when a mobile units moves from one cell to another, the mobile must

always be reassigned a new transmit and receive frequency to use in the new cell. This process, known as hand-off, must occur quickly, so that a call in progress is not interrupted during the normal course of events. However, in certain instances, such as when the mobile is in a rapidly moving automobile, or when there are no empty channels in the new cell, the call may be terminated.

There are at least two factors which determine whether an attempt to hand-off a call will succeed. These factors include the rate at which the mobile unit passes through the cells, and the non-uniformity of the electromagnetic field in the cell. Both factors relate to the time required to determine the relative location of the mobile unit, and to then transfer control of the mobile unit from the base station of the original cell to the base station of the new cell.

The location of the mobile unit is typically determined by comparing the field signal strength of the radio signal as received at the original base station and as received at the new base station. Because electromagnetic fields are usually non-uniform, this measurement of signal strength is typically made a number of times and then averaged. Unfortunately, the time required to accurately perform this measurement becomes longer as the turbulence of the electromagnetic field increases, such as may occur in a urban environment, or as the required accuracy of the signal strength measurement increases.

Even if the received signal strength measurement can be made quickly and accurately, additional processing must occur in order to hand-off of the mobile unit to an adjacent cell. In particular, one or more candidate new cells must be queried for idle channel status, and to verify the signal strength in the candidate cells. Making this status and verification inquiry usually requires the intervention of a higher level system controller, in addition to the control functions in the serving and candidate cells. Additional time must also be allotted for the mobile unit to tune to the new frequency in the candidate cell, and to confirm that it is operating properly.

One way to cope with the ever-increasing demand for cellular services is to shrink the size of the cells. However, as the density of cells increases, the need for hand-offs also increases. At certain cell densities, the time to process a hand-off may become a significant factor in the ability of such systems to consistently provide reliable telecommunication service. For example, in certain proposed PCS systems, the cells may be as small as five hundred (500) feet in radius. Thus, a mobile unit traveling only a few feet may require the handing off of the unit from one base station to a second and perhaps even to a third base station.

It can now be appreciated that a significant amount of time and system resources may be required for hand-off processing.

Accuracy in detecting the need for call hand-off, and the time necessary to complete the task, can be improved by using one or more diversity combining techniques. These techniques recognize that electromagnetic propagation of radio frequency energy, in certain environments, may take place not only by direct line-of-sight, but also by way of scattering. In particular, radio signals may be reflected by physical terrain features or buildings and/or refracted by the atmosphere before reaching the mobile receiver. Accordingly, the received signals may actually each consist of many waves arriving along multiple paths. Such multipath propagation in turn results in fading of the received electromagnetic energy according to a Rayleigh probability distribution.

Diversity combining techniques compensate for this fading by generating a number of signal transmission paths, or diversity branches, each of which carry the same information signal, but which have uncorrelated multipath fadings. The diversity branches are then combined in some way to resolve the actually transmitted signal.

Diversity techniques can be generally classified into those that make use of space, angle, polarization, frequency and/or time to generate the diversity branches. Space diversity, the approach which is of interest here, has been the most widely used, most likely because it can be implemented simply and economically. In this approach, a single

transmitting antenna and a number of receiving antennas are used. The spacing between receiving antennas is chosen such that the multipath fading appearing in each diversity branch is uncorrelated. In the typical cellular system employing space diversity combining, it thus is necessary then to have at least two receive antennas at each base station site. The multiple signals from the multiple antennas are then combined in some way to resolve the transmitted signal.

Thus, it would be desirable to reduce the complexity of the operations required in detecting and then handing off a call as a mobile unit travels from cell to cell, with a minimum number of base station antennas and associated receiver processing and control equipment.

SUMMARY OF THE INVENTION

Briefly, the invention is a cellular communication system in which each base station includes a wideband transceiver subsystem. The transceiver subsystem makes use of a wideband digital filter bank analyzer, or so-called channelizer, to receive a number of contiguous channels comprising a significant portion of the entire bandwidth serviced by the base station. The base station transceiver also makes use of a wideband digital filter bank synthesizer, or so-called combiner, to transmit on a number of contiguous channels.

A set of digital signal processors (DSPs) associated with the channelizer serve to demodulate the individual channel signals. As part of the demodulation process, each DSP periodically detects a receive signal strength indication (RSSI) for each of the channels available to the service provider. The channel RSSIs for each base station are then periodically reported to a central controller responsible for coordinating the operation of multiple base stations.

The central controller also attempts to assign a given mobile the same transmit frequency as it moves from cell to cell. In order to perform a diversity detection, the central controller can then simply compare the RSSI's for each channel as received from

all base stations, to determine which base station is reporting the strongest RSSI for that channel. The central controller then simply enables the corresponding transceiver channel in the base station which reported the largest RSSI.

There are several advantages to this arrangement.

Since the remote units maintain the same frequency from cell to cell, the invention eliminates the need for call hand-off procedures between adjacent base stations. This greatly reduces the amount of required frequency planning, since frequencies need not be assigned on a per-cell basis, but rather can be assigned as a call becomes active.

The invention also provides a convenient way to implement the advantages of diversity combining, which was heretofore only though possible with multiple antennas per base station site. In particular, since the signal transmitted by any given remote unit on any frequency will be received by any number of base stations, the central controller can perform all required diversity calculations, needing only one antenna and one wideband transceiver per cell.

In addition, because there are wideband transceivers located at every base station site, it is possible to have any number of active remote units within a particular cell. As a result, the ability of the system to adapt to changes in traffic patterns is greatly improved, without the need for frequency allocations to be made among the cells in advance. Because a mobile unit is assigned to a frequency as is moves from cell to cell, the available channel capacity automatically tends to move to wherever the traffic is heaviest.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and further advantages of the invention may be better understood by referring to the following description in conjunction with the accompanying drawings in which:

Fig. 1 is a block diagram showing the interconnection of base station transceiver subsystems and a base station controller which may be employed in the present invention;

Fig. 2 is a more detailed block diagram of the base station transceiver subsystem;

Fig. 3 is a geographic illustration indicating the area covered by a set of hexagonal cells for which radio transmission and reception occurs from base stations located at the center of the hexagonal patterns;

Fig. 4 is a block diagram of a basestation controller, including diagrams of various databases maintained by the controller; and

Figs. 5A, 5B and 5C are flow charts showing the sequence of steps performed by the controller to determine the manner in which operating frequencies are assigned to mobile units, and in the manner in which a diversity decision is made in the processes of activating particular base stations for each transmit channel.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Fig. 1 is a block diagram of a cellular communications system in which a number of mobile subscriber terminals (mobiles) 10 exchange radio frequency (RF) signals with a cluster of base station transceiver subsystems (BTSs) 11a, 11b, ...,11s (also collectively referred to here as the base stations 11), via a wideband multichannel transceiver 40. The RF signals are modulated with information specified by a number of individual voice and/or data signals, referred to here collectively as the channel signals 45. The base stations 11 in turn connect the channel signals 45 to other telecommunications equipment such as that connected to the Public Switched Telephone Network (PSTN) 200, via a mobile telephone switching office (MTSO) or mobile switching center (MSC) 100, as shown.

A transceiver control processor 50 associated with each base station 11 effects these connections by communicating with a central base station controller 120. In accordance with the invention, the base station controller 120 instructs the transceiver controllers 50 to maintain the same operating frequency, to the extent possible, for a particular remote unit 10 as it moves between different cells, under control of different base stations 11. The base station controller 120 also periodically receives signal strength indication (RSSI) measurements for each frequency channel available to the system operator from each transceiver controller 50. These RSSI reports include a receive signal strength measurement for each of the receive channels at each of the wideband multichannel transceivers 40. The base station controller 120 then operates on this set of RSSI measurements for each receive channel to determine which of the transceivers 40 in each base station 11 should be activated.

Turning attention now to Fig. 2, an exemplary base station transceiver subsystem (BTS) 11a consists of a transceiver portion 40 and transceiver control processor 50. The transceiver 40 acts as the radio interface for the channel signals 45, and includes radio receiver and radio transmitter equipment to provide access to a number of contiguous receive and transmit channels simultaneously. The transceiver control processor 50 coordinates the operation of the transceiver 40, according to commands received from the MSC 100.

In particular, the transceiver 40 consists of an antenna 12 which is coupled to both a wideband multichannel receiver 13 and a wideband multichannel transmitter 19 via a duplexer 25. (Alternatively, separate transmit and receive antennas may be coupled to the receiver 13 and transmitter 19.)

The wideband receiver 13 portion of the base station 11a consists of a downconverter 14, an analog-to-digital (A/D) converter 15, one or more digital filter bank analyzers, or channelizers 16, a time division multiplex bus 17, and a plurality of digital signal processors (DSPs) which are programmed to operate as demodulators 18-1, 18-2,...,

18-p (collectively demodulator DSPs 18). The demodulator DSPs 18 each provide one of the demodulated channel signals 45 at its output. A transport encoder 30 may be used to receive the outputs of the demodulator DSPs 18 and encode them into a suitable signaling format for transport to the MSC 100, such as the well-know T1 format.

The wideband transmitter 19 portion performs the reciprocal functions in the transmit direction. In particular, the transmitter 19 consists of a transport signal decoder 32, a plurality of modulator DSPs 20-1, 20-2,...,20-p, each of which receive one of the channel signals at an input, a digital filter bank synthesizer, or combiner 22, a digital-to-analog converter 23, and an up-converter 24, which in turn feeds the antenna 12 through the duplexer 25.

The transceiver control processor 50 is a computer, such as a microcomputer, and includes a central processing unit (CPU) 52, a memory 53, and an input/output interface 54. To facilitate communication with the wideband transceiver 40, the transceiver control processor 50 also makes use of a Time Division Multiplex (TDM) bus controller 55 and a VME bus controller 56. A modem 57 may be used to communicate with the base station cluster controller 120.

As mentioned above, the base station 11a exchanges radio frequency (RF) signals with a number of mobile subscriber terminals (mobiles) 10. The RF signals are modulated as specified by any of a number of wireless air interface standards, such as the well-known Advanced Mobile Phone Service (AMPS) standard, or with other modulation schemes.

The RF modulated signals from the mobiles 10 are first received at the antenna 12, and forwarded through the duplexer 25 to a wideband digital tuner consisting of a downconverter 14 and analog to digital (A/D) converter 15. The digital downconverter 14 frequency-translates the received RF signal to a intermediate frequency (IF) prior to analog to digital (A/D) conversion 15, to produce a digital composite signal for input to the channelizer 16.

The downconverter 14 is wideband in the sense that it covers a substantial portion of the bandwidth available to the wireless service provider who is operating the base station 11a. For example, the wideband digital tuner may downconverter a 12.5 MegaHertz (MHz) bandwidth in the 800-900 MHz range which contains as many as 416 receive and transmit channel signals, each having an approximately 30 kiloHertz (kHz) bandwidth.

The digital channelizer 16 separates the downconverted composite digital signals to a plurality, N, of digital channel signal outputs, with each channel signal output representing a corresponding one of the individual 30 kHz bandwidth channel signals. The digital channelizer 16 can thus be considered as a bank of contiguous-in-frequency digital filters, with each filter having a 30 kHz bandwidth. The digital channelizer 16 may implement the filter bank using any of several efficient band pass filter structures, and no particular digital filter structure is critical to the operation of the invention.

A co-pending United States patent application entitled "Transceiver Apparatus Employing Wideband FFT Channelizer with Output Sample Timing Adjustment and Inverse FFT Combiner for a Multichannel Communication Network" filed April 8, 1994 and which is assigned to AirNet Communications, Inc., the assignee of this application, describes the details of several preferred embodiments of the digital channelizer 16 which make use of a convolutional digital filter 16-1 and fast Fourier transform (FFT) unit 16-2.

The N digital channel signals are then provided over the time division multiplex (TDM) bus 17 to a plurality of digital signal processors (DSPs) programmed to perform demodulation 18-1, 18-2, ..., 18-p (collectively, demodulator DSPs 18). The TDM bus 17 operates as a time division multiplexed cross-bar switch. That is, any one of the N digital channel signals may be connected to any one of the demodulator DSPs 18 via the TDM bus 17. A TDM bus controller 51 insures the proper timing of the signals on the TDM bus 17 to effect the required connections in the proper order.

The demodulator DSPs 18 are programmed to remove the modulation on one of the channel signals specified by the air interface standard in use. There typically is not a one-to-one correspondence between the number of demodulator DSPs 18 and the number of channel signals, N, provided by the channelizer 16. For example, the demodulator DSPs 18 may each process a number of digital channel signals at the same time, or, it may be necessary to use more than one DSP to demodulate a given channel. The demodulated channel signals are then encoded by the transport encoder 30, and ultimately connected to the PSTN 100, through an MSC switch 110.

The signal flow on the transmit side of the base station 11a is analogous. Signals received from the MSC switch 110 are decoded and then coupled to a set of modulator DSPs 20. The modulator DSPs 20-1, 20-2, ..., 20-p, in turn, modulate these signals and presents them to the TDM bus 17. These modulated signals are then each forwarded over the TDM bus to one of the N digital channel signal inputs to the combiner 22. As was true in the receive direction, the TDM bus 17 permits any one of the modulator DSPs 20 to be connected to any one of the channel signal inputs to the combiner 22. The digital combiner 22 then combines the N channel signals to synthesize a composite digital signal using an inverse FFT 22-1 and filter 22-2. The digital combiner 22 feeds this composite signal to a digital to analog (D/A) converter 23 and up-converter 24 which generates an RF signal 27. This RF signal 27 is then typically amplified by a power amplifier (not shown) and fed to the transmit antenna 25.

A more detailed description of the digital combiner 22 is also contained in the above-mentioned co-pending patent application.

As mentioned previously, the present invention lies in the manner in which the base station controller 120 assigns frequencies to the mobile units and the manner in which base station transceiver channels are activated, to both minimize the need for hand-offs as well as to provide diversity reception, with only one antenna per cell.

In order to accomplish this, the base station controller 120 makes use of data provided by the demodulator DSPs 18. In particular, the demodulator DSPs 18 each output a receive signal strength indication (RSSI), which is a value representing the relative power level of the signal received in each channel. These RSSI reports may be made to the transceiver controller 50 in any convenient fashion, such as by using a control bus such as the illustrated industry standard VME bus 21. The RSSI reports from multiple channels are then forwarded by the transceiver controller 50 to the base station controller 120 over some other suitable interface, such as the modem 57. The controller 120 then processes these RSSI reports from the various base stations 11 to determine how to activate particular base stations, on a per channel basis.

More particularly, consider that the service area in a cellular mobile telephone system can be conceptualized as a packing of hexagonal areas, or cells, with each cell having definite and sharp boundaries, as shown in Fig. 3. In a common arrangement, a base station 11a, 11b, ..., 11s is located in the center of each corresponding cell, A, B, ..., S. Frequency assignments are made to the cells in a fixed, repeating pattern. A common pattern is to repeat the assignments in groups of seven cells, so that no frequency is ever active in two adjacent cells. For example, the N available channels would, in the prior art, be evenly divided among cells A, B, C, D, E, F, and G so that only N/7 channels are available at most in each cell.

There is, however, an ever increasing need to service a greater number of mobile units in a given area. One way that this need has been met in prior systems is by reducing the size of each cell, which in effect, adds more cells to cover each given physical area, to increase the frequency reuse level. Unfortunately, as the number of base stations in a given area increases, the number of call hand-offs between the base stations, as well as the time required to process the hand-offs, may become objectionable.

To overcome these difficulties, the invention first insures that frequency assignments are made to the mobile units in a particular way. For example, a mobile 10

may travel from a first cell A under control of base station 11a at time t_A, to a second cell B under control of base station 11b at time t_B. The same mobile may subsequently travel to cell I under control of base station 11i at time t_I. In accordance with the invention, the base station controller 120 attempts to maintain a fixed transmit and receive channel assignment, f_t and f_r, at all times t_A, t_B, and t_I. That is, unlike prior systems, when the mobile unit 10 moves from cell A to cell B, as long as the frequencies f_t and f_r are not in use in any other cells adjacent to the new cell B, namely cells G, H, H, J, K, L, and D, then the mobile unit 10 is permitted to continue operating on frequencies f_r and f_r. As a result, frequency hand-off procedures are not needed while the mobile 10 moves in this manner.

Because of this frequency assignment paradigm, the invention can thus more easily determine which one of the base stations 11a, 11b, ..., 11s will provide the best radiated signal strength to and from the mobile 10, without the need for multiple antenna elements at each base station 11, or in the remote units 10. This is possible because each of the base stations 11 provides outputs representing the receive signal strength indication (RSSI) in each of the radio frequency channels operated by the service provider. Unlike prior art systems then, diversity determination is thus greatly simplified, since a received signal strength measurement is always available for each assigned frequency, and is available for each of the base stations 11, without waiting for the mobile 10 to switch to a newly assigned frequency.

The remaining drawings illustrate the manner in which the invention may be implemented in the base station cluster controller 120.

Fig. 4 is a block diagram of the base station cluster controller 120. It is a conventional microprocessor, and includes a central processing unit (CPU) 120-1, a memory 120-2, a disk 120-3, a modem 120-4, and an input/output controller 120-5, and a modem 120-4, and a disk 120-5.

In general, the cluster controller 120:

(1) instructs the base stations 11 to maintain a fixed operating frequency for a given mobile unit 10, to whatever extent possible as that given mobile unit 10 moves from cell to cell; and

(2) receives RSSI reports for each of the frequencies available to the service provider from each of the base stations 11, and in response thereto, activates particular transmit channels of the combiners 22 and particular receive channels in the channelizers 16 depending upon these RSSI reports.

In order to accomplish these tasks, the cluster controller 120 maintains several databases, or tables, in its memory 120-2 and/or disk 120-3.

As shown in Fig. 4, an RSSI table 121 contains several sections 121-1, 121-2, ..., 121-s for each of the S base stations 11 serviced by the base station controller 120. An exemplary section 121-S contains a list of N data values corresponding to the RSSI value for each of the N possible channel frequencies f_1, f_2, ..., f_N for base station number S.

An active base station table 122 contains entries indicating which of the S base stations 11 are actively operating on each of the channel frequencies f_1, f_2, ..., f_N. Each entry thus consists of a value which identifies one of the base stations A through S, or a null value indicating that the frequency is not is use.

A mobile frequency assignment table 123 indicates the frequencies f_t and f_r which have been assigned to each mobile unit for both transmitting and receiving, respectively.

Figs. 5A, 5B, and 5C are flow charts of the steps performed by the CPU 120-1 in the base station controller 120 according to the invention. It should be understood that the controller 120 only performs these steps periodically, and will be performing other tasks at the same time which are not related to the novel features of this invention.

Referring to Fig. 5A, from an idle state 500, the controller 120 performs a step 501 in which it receives a report of RSSI levels from one or more of the S base stations. These

reports from the transceiver controllers 50 includes an RSSI level for each of the N channels covered by the associated multichannel transceiver 40.

In a next step 502, the cluster controller 120 uses information in the RSSI reports to update its internal RSSI table 121. Thus, even if not all of the base stations 11 report their respective RSSI levels at the same time, the internal RSSI table 121, over time, eventually does contain all information concerning the receive power levels for each of the N frequencies available to the service provider for each of the S base stations 11.

A second sequence of steps are also performed from time to time by the controller 120. As shown in Fig. 5B, from an idle state 510, the controller 120 receives a report from one or more of the base station controllers 50 of a new mobile unit requesting service. In step 512, the controller 120 searches its active base station table 123 to identify a new transmit and receive operating frequency, f_t and f_r, from the N possible frequencies which are not already in use in the cell where the mobile is located and in the surrounding cells.

For example, as shown in Fig. 3, if the new mobile is in cell A, then a frequency pair, f_t and f_r, are chosen which are not already in use in cells A, B, C, D, E, F, or G. The identified frequency pair is then forwarded to the requesting base station to be used in turn by the new mobile unit.

In step 513, the cluster controller updates its active base station table 122 and mobile frequency assignment table 123 with the newly assigned transmit and receive frequencies.

Referring to Fig. 5C, the controller 120 also periodically performs a third sequence of steps to determine the need for performing a hand off. From an idle state 520, the controller 120 performs a series of steps for each of the N channels.

First, it determines which of the base stations is reporting the greatest RSSI for a particular channel, in step 522. This is done by searching through the RSSI table 122.

Secondly, in step 523, a diversity decision is made, by determining if the base station reporting the greatest RSSI for the channel determined in step 522, is the same as the last time the comparison was made. This is typically done by examining the contents of the active base station table 122 for the current frequency, to see if the base station ID stored there is the same as the base station determined in step 522.

If these are the same, then control returns to step 521 where another channel is processed.

If, however, these are different, then the mobile has moved to a different cell, and control passes to step 524. In that step, a determination is made as to whether the mobile unit must be assigned a new frequency pair, f_t and f_r. In particular, the frequency assignment table 123 is consulted to determine if the frequencies f_t and f_r are free for use in each of the five other cells surrounding the new cell. For example, referring back to Fig. 3 briefly, if the mobile unit has moved from cell A to cell B, then step 524 determines whether f_t and f_r are available in each of cells C, G, H, I, and J.

If this is so, then control passes to step 525, where the mobile is permitted to continue operating on the same frequencies. Thus, the usual hand-off instructions and delay required to switch the mobile to a new frequency are avoided.

If, however, the frequencies f_t and f_r are in use in the cells surrounding the new cell, then control passes to step 526, where a new pair of frequencies is selected. Hand off procedures are then performed in step 527, by issuing instructions to the mobile 10 to tune to the new transmit and receive frequencies. In addition, the entries in the active base station table 122 and frequency assignment table 123 are updated.

This manner of processing signals received from the base stations 11 by the cluster controller 120 results in several characteristics of a system according to the invention.

First, because the same frequency can be maintained for a given mobile unit as it travels from cell to cell, and because any base station 11 processes receive signal strength

indications for each of the N possible active channels continuously, conventional hand-off procedures which require the mobile to change frequency as it moves from cell to cell are eliminated.

Secondly, the cluster controller 120 always determines the received signal strength from at least two of the base stations, using the RSSI outputs for the same frequency from both the base station outputs. The transmit channel associated with the base station having the strongest received signal strength is then automatically activated. The advantages of a space diversity system are thus achieved, since the location of a strongest receiver and hence the optimum transmit base station antenna is determined automatically, without the need for multiple antennas at each base station site.

Thus, both the advantage of providing multiple antennas per call for space diversity combining, as well as the elimination of unnecessary hand-offs have been provided, while still requiring only one transmit and one receive antenna per cell.

What is claimed is:

CLAIMS

1. A cellular communications system comprising:

a plurality of base station means, each base station means associated with one of a number of sub-areas, or cells, of the geographic area covered by the system, each of the base station means connected to receive a wideband composite signal consisting of a number of channel signals transmitted by a number of mobile units, and for providing a number, N, of channel signals at an output, together with a receive signal strength indication, or RSSI, value for each of the N channels; and

base station controller means, connected to receive the RSSI values for the N channel signals from each of the base stations, and connected to control an operating frequency of at least one of the mobile units such that the operating frequency remains the same for as long as that one mobile unit moves into a new cell where the operating frequency is not already in use in that new cell and not already in use in a cell immediately adjacent to the new cell, for comparing the RSSI values for a given digital channel signal from each of the base stations, to determine which one of the base stations has a maximum RSSI value for the given channel, and for activating the base station so determined for operation on that given channel.

2. A system as in claim 1 wherein the base station controller means assigns the one remote unit an operating frequency from any of N frequencies allocated to the service provider.

3. A system as in claim 1 wherein the base station cluster controller maintains a table of RSSI values containing N entries for each base station.

4. A system as in claim 1 wherein the base station cluster controller maintains a table of active base stations indicating which of the base stations is active on each of the N channel frequencies.

5. A system as in claim 1 wherein the base station cluster controller maintains a table of mobile frequency assignments indicating which of the N frequencies have been assigned to which mobile units.

6. A system as in claim 5 wherein the base station cluster controller means includes means for receiving reports of a new mobile unit requesting access to the cellular system, and for selecting a frequency to be used by the new mobile unit by selecting one of the N frequencies which are not listed in the table of mobile frequency assignments as being in use in the cell in which the new mobile unit is located or in any of the cells immediately adjacent thereto.

7. A system as in claim 1 wherein the base station cluster controller means additionally compares the maximum RSSI value against a predetermined threshold value, to determine if a hand off to another base station is required.

8. A system as in claim 1 wherein the base station cluster controller means additionally includes means for iteratively identifying which one of the base stations is reporting the maximum RSSI value, and, when the identity of that base station changes, for deactivating a current base station transceiver for the current channel, and for activating a new base station transceiver for the current channel.

9. A cellular telephone system consisting of a cluster of cells, with a base station transceiver associated with each of the cells, the base station transceivers for transmitting and receiving signals from a number of remote mobile units, wherein the improvement comprises:

means for allowing each of the base station transceivers to transmit and receive signals on each of a number, N, of channel frequencies which have been made available for use in the cellular telephone system;

means for maintaining a given operating frequency for at least one of the mobile units as it moves from cell to cell within the cluster of cells;

means for determining a receive signal strength at the given operating frequency for at least two of the base station transceivers;

means for comparing the receive signal strength for the at least two base station transceivers at the given operating frequency, to identify one of the at least two base stations as the base station receiving a strongest signal from the at least one mobile unit; and

means for activating the identified base station for communication with the at least one mobile unit.

10. A method of operating in a cellular mobile telephone system consisting of a plurality of base stations, each base station having a single transmit and single receive antenna, and each base station receive antenna being coupled to a wideband digital channelizer that provides a plurality of digital channel signals representing the signal energy received in a bank of contiguous base station receive channels, the method comprising the steps of:

determining a list of active receive channels for all base stations by comparing a receive signal strength indication for each receive channel for each base station against a predetermined threshold value; and

for each active receive channel so determined,

determining which of the base stations in the cluster receives a given digital channel signal with a greatest received signal strength indication;

activating the associated transmit channel in the base station so determined for that given digital channel signal; and

maintaining the transmit and receive channel assignments as the mobile moves from cell to cell as long as the mobile moves into a new cell where the transmit and receive channels are not already in use in any of the cells immediately adjacent to the new cell.

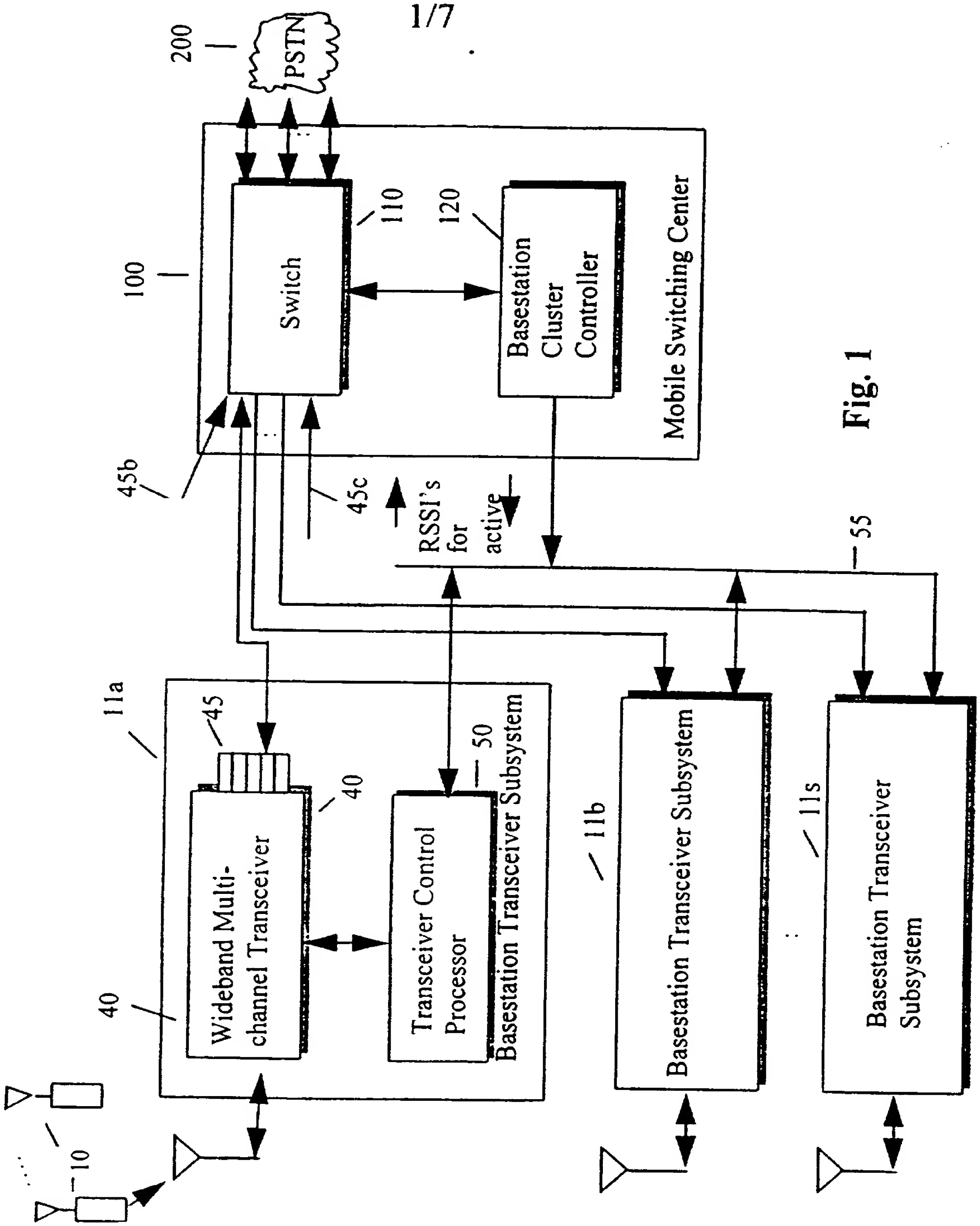

200
PSTN
100
Switch
110
120
Basestation
Cluster
Controller
Mobile Switching Center
45b
45c
RSSI's
for
active
55
11a
45
40
50
Wideband Multi-
channel Transceiver
Transceiver Control
Processor
Basestation Transceiver Subsystem
11b
Basestation Transceiver Subsystem
11s
Basestation Transceiver
Subsystem
10

Fig. 1

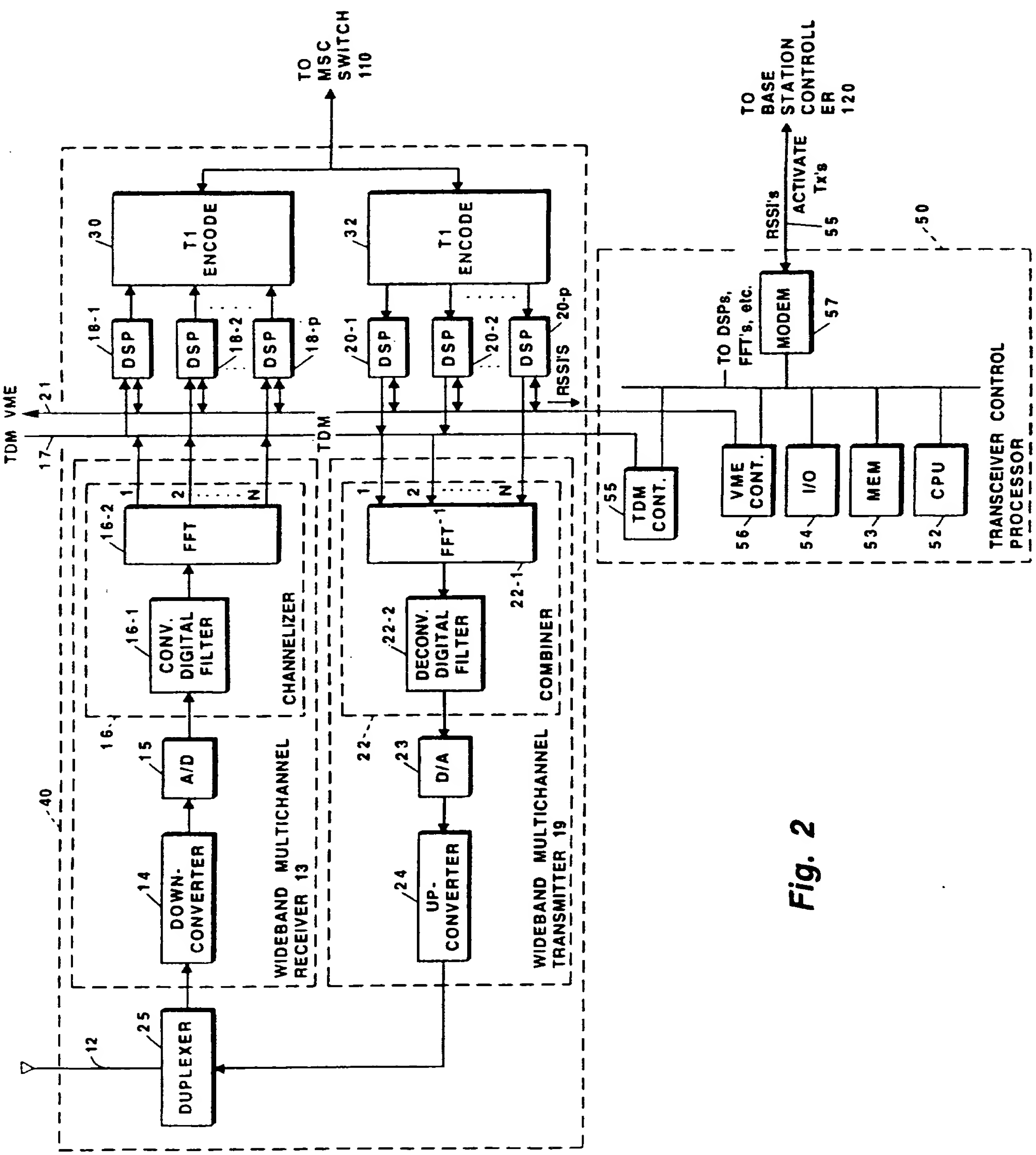
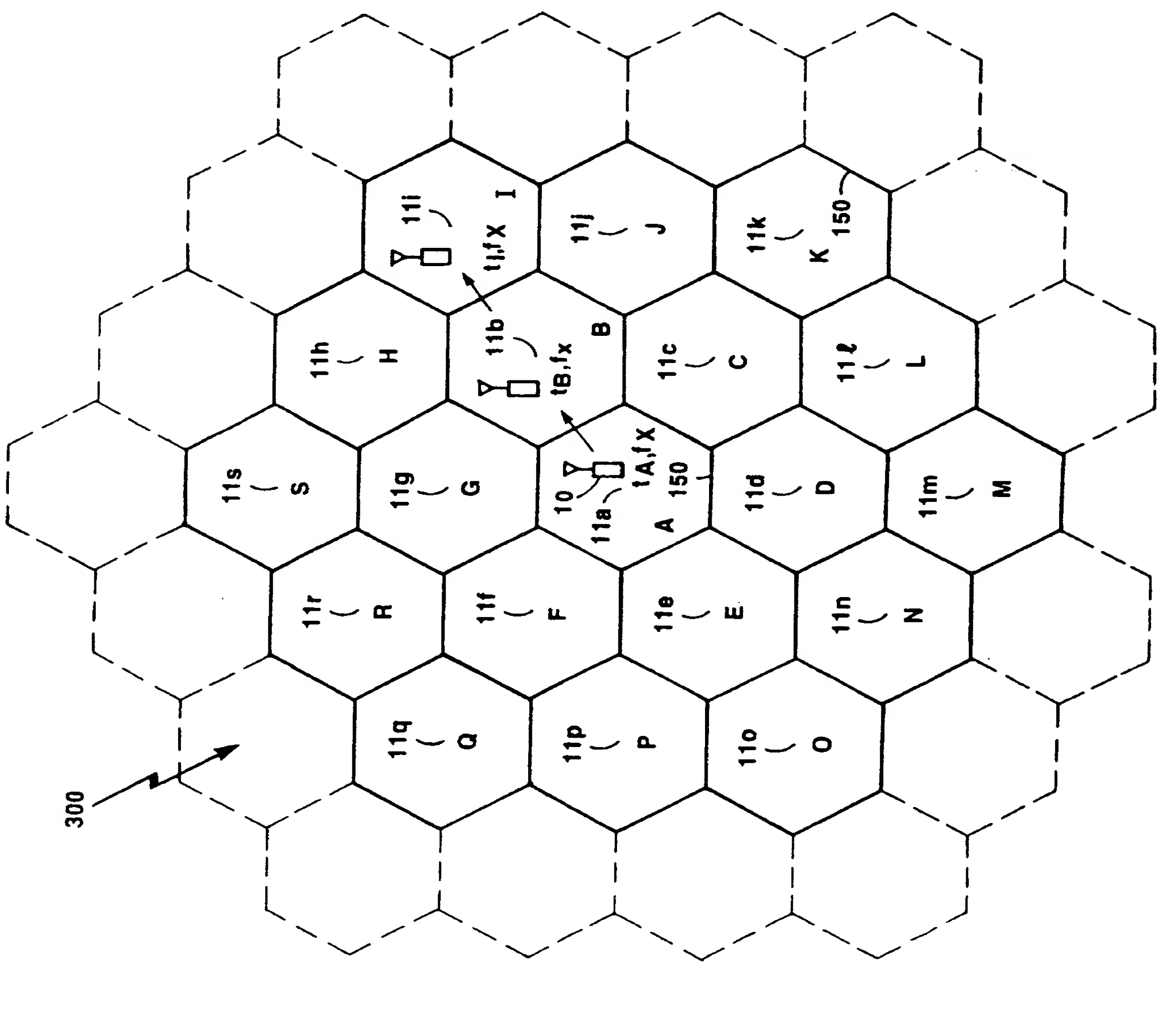
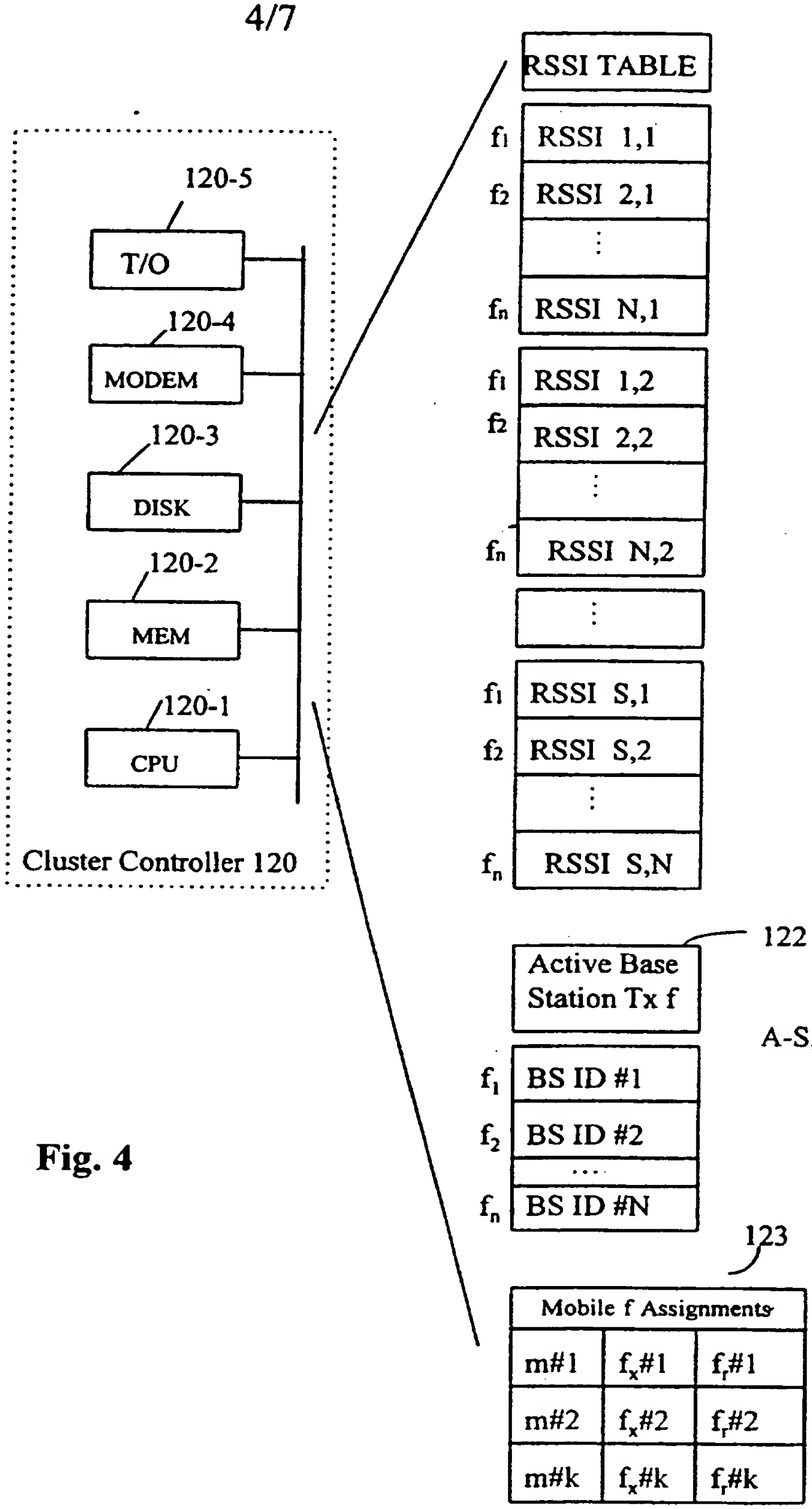

TO MSC SWITCH 110
TO BASE STATION CONTROLLER 120
RSSI's
ACTIVATE Tx's
55
50
T1 ENCODE
30
T1 ENCODE
32
DSP
18-1
18-2
18-p
20-1
20-2
20-p
RSSI'S
TO DSPs, FFT's, etc.
MODEM
57
TDM VME
21
17
TDM
FFT
16-2
1
2
N
22-1
CONV. DIGITAL FILTER
16-1
DECONV. DIGITAL FILTER
22-2
CHANNELIZER
COMBINER
16
22
A/D
15
D/A
23
DOWN-CONVERTER
14
UP-CONVERTER
24
WIDEBAND MULTICHANNEL RECEIVER 13
WIDEBAND MULTICHANNEL TRANSMITTER 19
40
DUPLEXER
25
12
TDM CONT.
VME CONT.
I/O
MEM
CPU
56
54
53
52
TRANSCEIVER CONTROL PROCESSOR

Fig. 2

Fig. 3


300
10
11a
A
fA,fX
150
11b
B
fB,fx
11i
I
fI,fX
11j
J
11k
K
150
11c
C
11h
H
11ℓ
L
11s
S
11g
G
11d
D
11m
M
11r
R
11f
F
11e
E
11n
N
11q
Q
11p
P
11o
O



120-5
T/O
120-4
MODEM
120-3
DISK
120-2
MEM
120-1
CPU
Cluster Controller 120
RSSI TABLE
f1 RSSI 1,1
f2 RSSI 2,1
fn RSSI N,1
121-1
f1 RSSI 1,2
f2 RSSI 2,2
fn RSSI N,2
121-2
f1 RSSI S,1
f2 RSSI S,2
fn RSSI S,N
121-S
122
Active Base Station Tx f
A-S, null
f1 BS ID #1
f2 BS ID #2
fn BS ID #N
123
Mobile f Assignments
m#1 fx#1 fr#1
m#2 fx#2 fr#2
m#k fx#k fr#k

Fig. 4

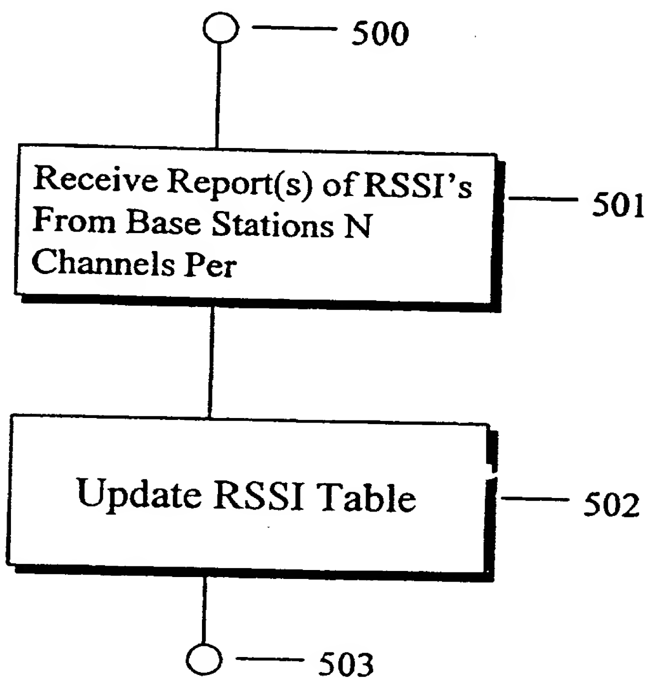

500
Receive Report(s) of RSSI's From Base Stations N Channels Per
501
Update RSSI Table
502
503

Fig. 5A

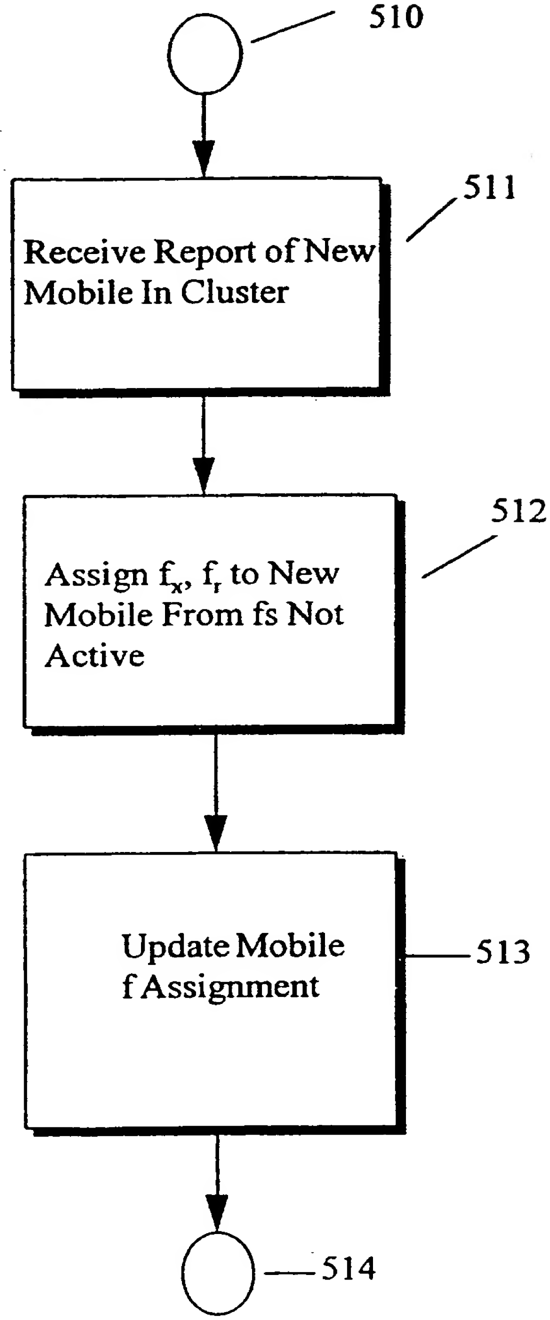

510
Receive Report of New Mobile In Cluster
511
Assign f_x, f_r to New Mobile From fs Not Active
512
Update Mobile f Assignment
513
514

Fig. 5B

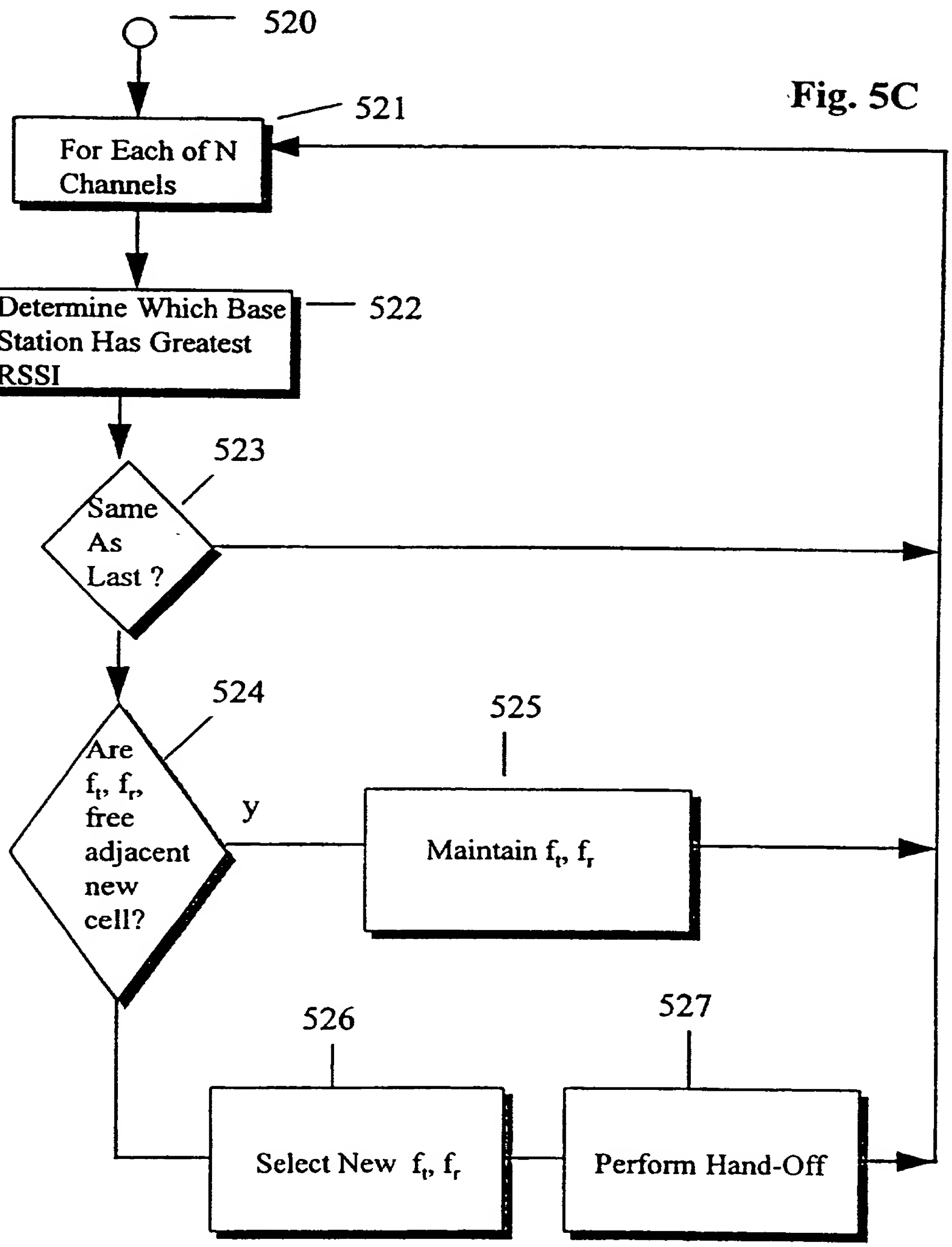

520
521
For Each of N Channels
Determine Which Base Station Has Greatest RSSI
522
523
Same As Last ?
524
Are f_t, f_r, free adjacent new cell?
y
525
Maintain f_t, f_r
526
527
Select New f_t, f_r
Perform Hand-Off

Fig. 5C

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 95/13104

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04Q7/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04Q H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO,A,94 05109 (MOTOROLA INC) 3 March 1994 see page 10, line 35 - page 14, line 1; figures 5,6 ---	1-5,7,9
A	EP,A,0 347 396 (ERICSSON TELEFON AB L M) 20 December 1989 see column 5, line 16 - line 46; figure 1 see column 13, line 13 - column 14, line 42; figure 2 ---	1,9
A	WO,A,91 07043 (PACTEL CORP) 16 May 1991 see page 6, line 34 - page 8, line 24; figure 1 see page 11, line 25 - page 12, line 27 -----	

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

1

Date of the actual completion of the international search	Date of mailing of the international search report
5 March 1996	18.03.96

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Bossen, M

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 95/13104

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
WO-A-9405109	03-03-94	CA-A-	2142964	03-03-94
		EP-A-	0657077	14-06-95
		US-A-	5392331	21-02-95
EP-A-0347396	20-12-89	DE-D-	68909121	21-10-93
		DE-T-	68909121	13-01-94
		EP-A-	0535714	07-04-93
		EP-A-	0537795	21-04-93
		ES-T-	2044221	01-01-94
		NO-B-	177770	07-08-95
		US-A-	5327577	05-07-94
		US-A-	5109528	28-04-92
WO-A-9107043	16-05-91	EP-A-	0502019	09-09-92
		JP-B-	7079508	23-08-95
		JP-T-	4507177	10-12-92
		US-A-	5067147	19-11-91